



Jet Propulsion Laboratory
California Institute of Technology

Improved Content-Based Image Classifiers for the PDS Image ATLAS

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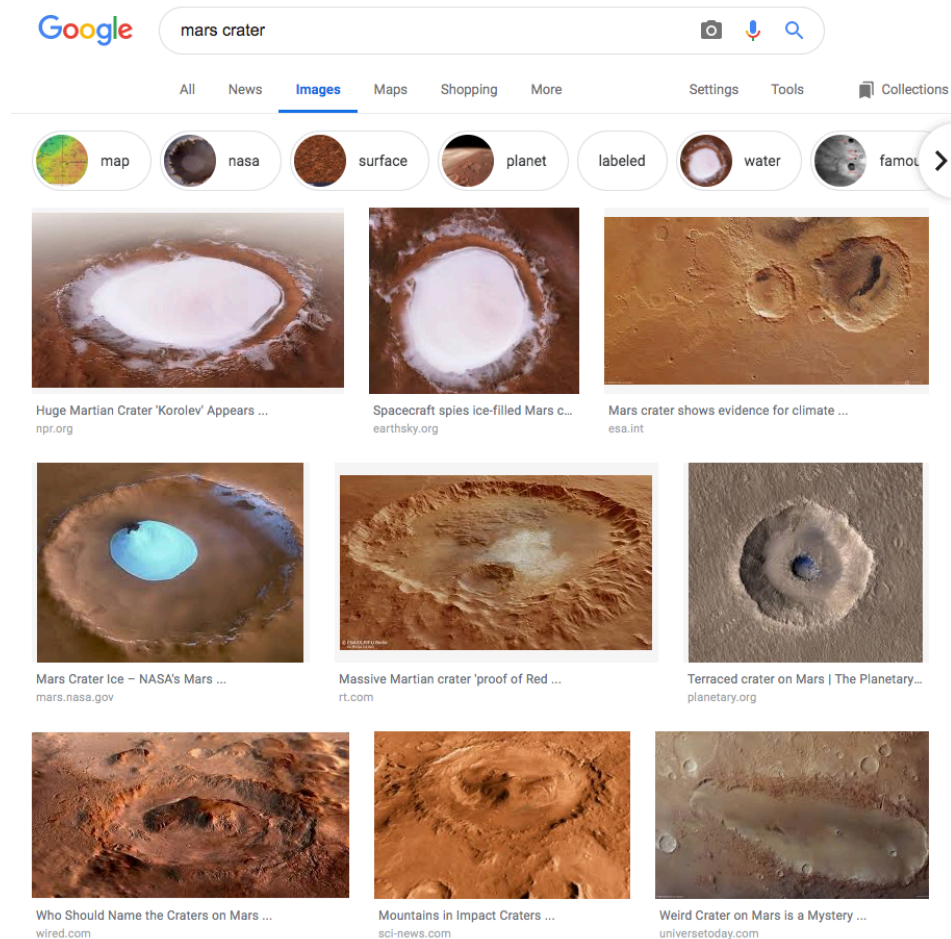
June 18, 2019

Current Mars Data Set Collections

- Surface Missions
 - 11.9M --- Mars Science Laboratory (MSL)
 - 7.1M --- Mars Exploration Rover (MER)
 - 1069 --- Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)
- Orbital Missions
 - 3.0M --- Mars Odyssey
 - 1.9M --- Mars Reconnaissance Orbiter (MRO)

How to Find What You Want?

Google search

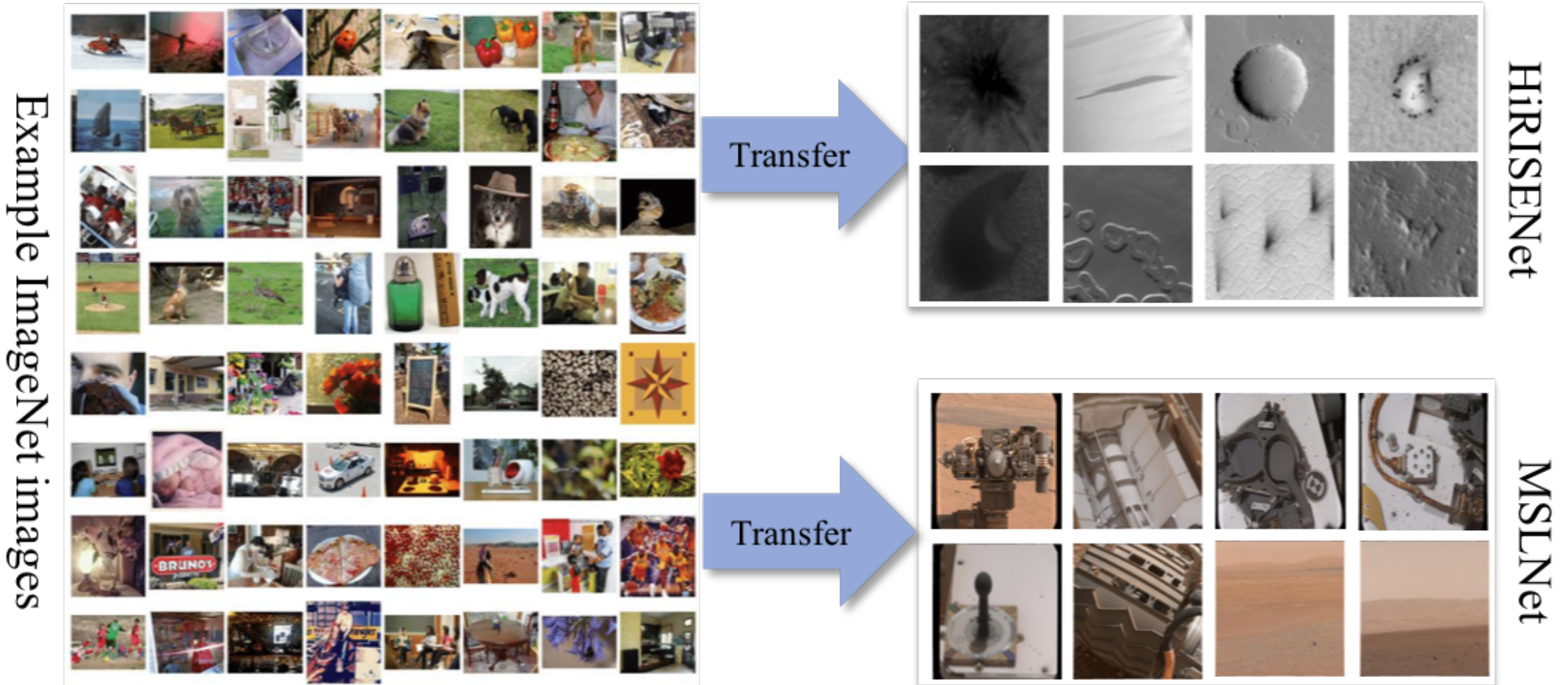


Manual examination



Machine Learning Solution

Transfer learning



MSL Rover Data Set

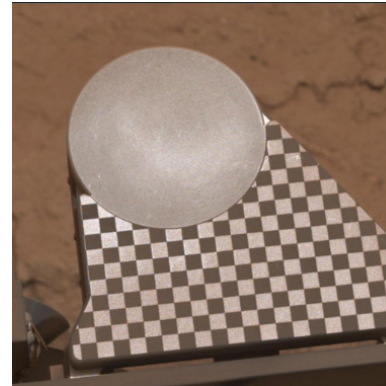
- 6691 labeled images
 - Collected from Mastcam Right eye, Mastcam Left eye, MAHLI
 - 3,746 training, 1640 validation, 1305 testing
 - 24 classes
 - Published under DOI [10.5281/zenodo.1049137](https://doi.org/10.5281/zenodo.1049137)



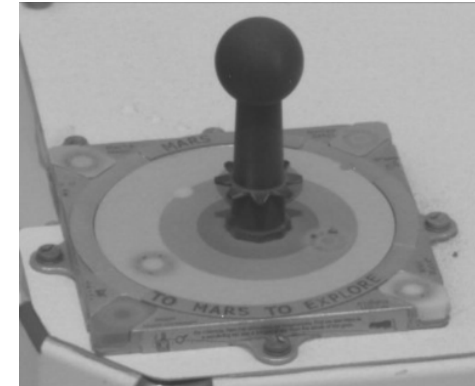
Drill hole



Wheel



Observation tray

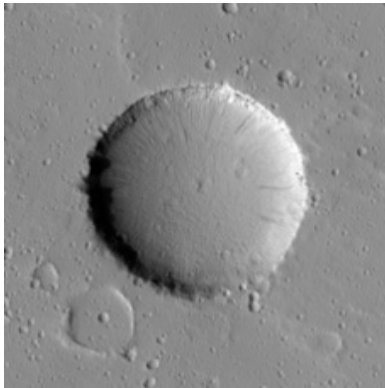


Mastcam cal target

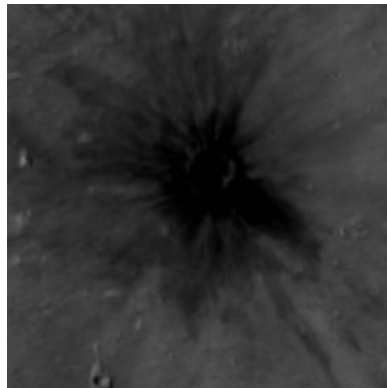
Example classes for MSL Rover data set. See full list at [Wagstaff et al, 2018, AIAA]

MRO HiRISE Data Set

- 73031 labeled images
 - Collected from MRO HiRISE camera
 - 46970 training, 13391 validation, 1810 testing
 - 8 classes
 - Published under DOI [10.5281/zenodo.2538136](https://doi.org/10.5281/zenodo.2538136)



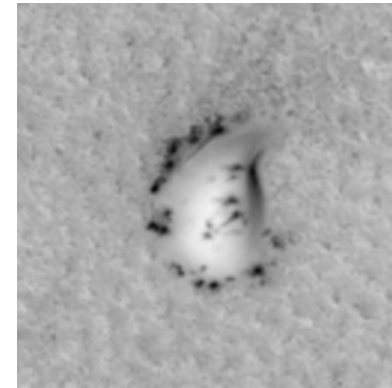
Crater



Impact ejecta



Slope streak

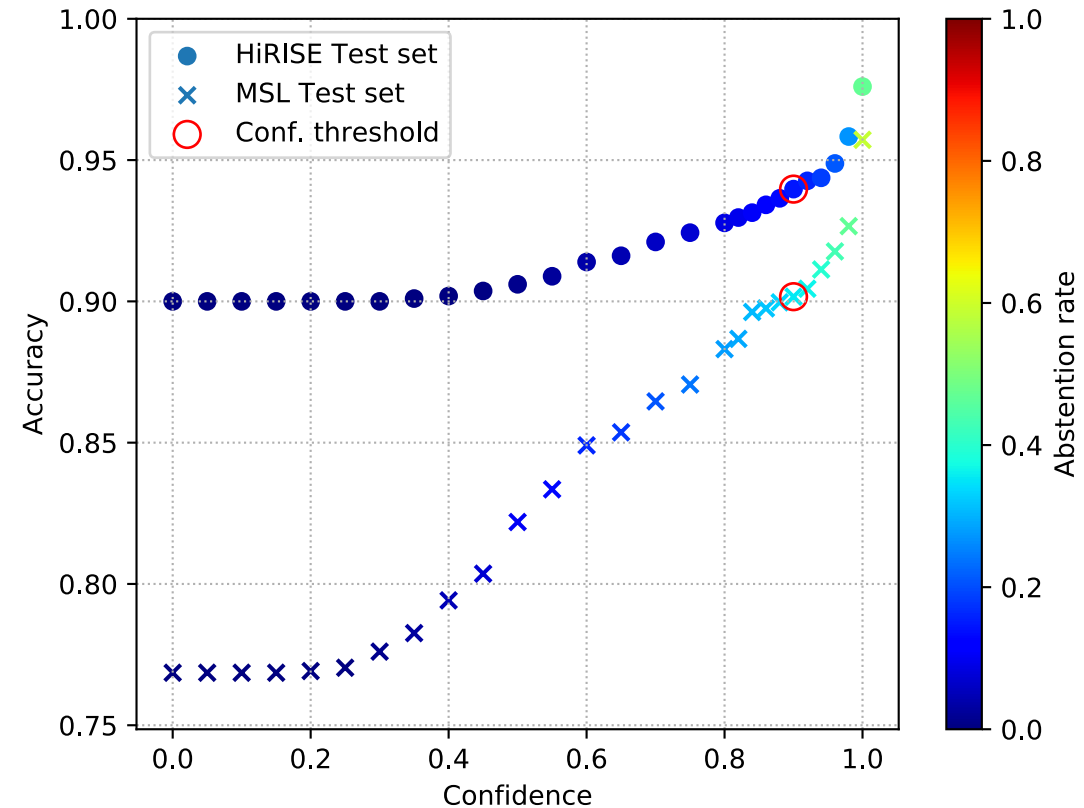


Bright dune


Example classes for MRO HiRISE data set

Evaluation


- Test set accuracy at 90% confidence
 - MSLNet: 76.9%
 - HiRISENet: 93.46%
- Test set abstention rate at 90% confidence
 - MSLNet: 35.3%
 - HiRISENet: 14.8%
- Classifier calibration
- Error analysis



http://pds-imaging.jpl.nasa.gov/search/

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PDS Image Atlas



Perform a text search like "mars crater" or "cassini rings", or a more advanced search like "TARGET_NAME:enceladus"

Show results for
(click to remove filter)

Share

Narrow your search by selecting a facet below











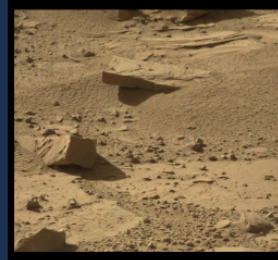



















- Mission
- Spacecraft
- Instrument
- Target
- Product Type
- Lighting Geometry
- Filters
- Lat/Lon Bounding Box
- Time Constraints
- Orbital Mission Constraints
- Landed Mission Constraints
- PDS Archive Constraints
- Advanced Constraints
- MRO HIRISE Image Content Beta
- MSL Image Content Beta
- Cassini ISS Image Content Beta
- Galileo SSI Europa Image Content Beta
- Maps
- Reports
- Bulk File Download

Results: 24 Page:

< 1 2 3 ... 1383124 1383125 > displaying 1 to 24 of 33194984

Thumbnail View List View Add field to sort by: MSL_CONFIDENCE

Select All Images: ☒ On Page ☐ In Query

 <p>0617MR0026000740401156E01_XXXX</p> <p>   </p>	 <p>0618MR0026010270401296E01_XXXX</p> <p>   </p>	 <p>0618MR0026010750401344E01_XXXX</p> <p>   </p>
 <p>0619ML0026020000302171E01_XXXX</p> <p>   </p>	 <p>0619ML0026020010302172E01_XXXX</p> <p>   </p>	 <p>0619ML0026020160302187E01_XXXX</p> <p>   </p>

MSL Rover Wheel Degradation

Show results for
(click to remove filter)

remove all
(x) MSL_IMAGE_CLASS:wheel
(x) MSL_CONFIDENCE:[95 TO 100]
(x) ATLAS_INSTRUMENT_NAME:mastcam
(x) PRODUCT_TYPE:rdr

- ▶ Mission
- ▶ Spacecraft
- ▶ Instrument
- ▶ Target
- ▶ Product Type
- ▶ Lighting Geometry
- ▶ Filters
- ▶ Lat/Lon Bounding Box
- ▶ Time Constraints
- ▶ Orbital Mission Constraints
- ▶ Landed Mission Constraints
- ▶ PDS Archive Constraints
- ▶ Advanced Constraints
- ▶ MRO HIRISE Image Content Beta
- ▼ **MSL Image Content** Beta


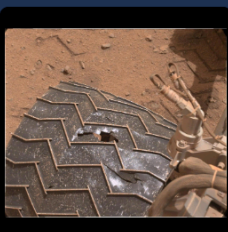
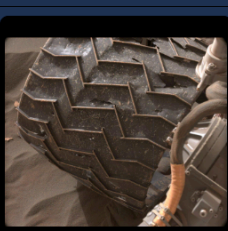
Image Class

wheel (4972)

Confidence Level

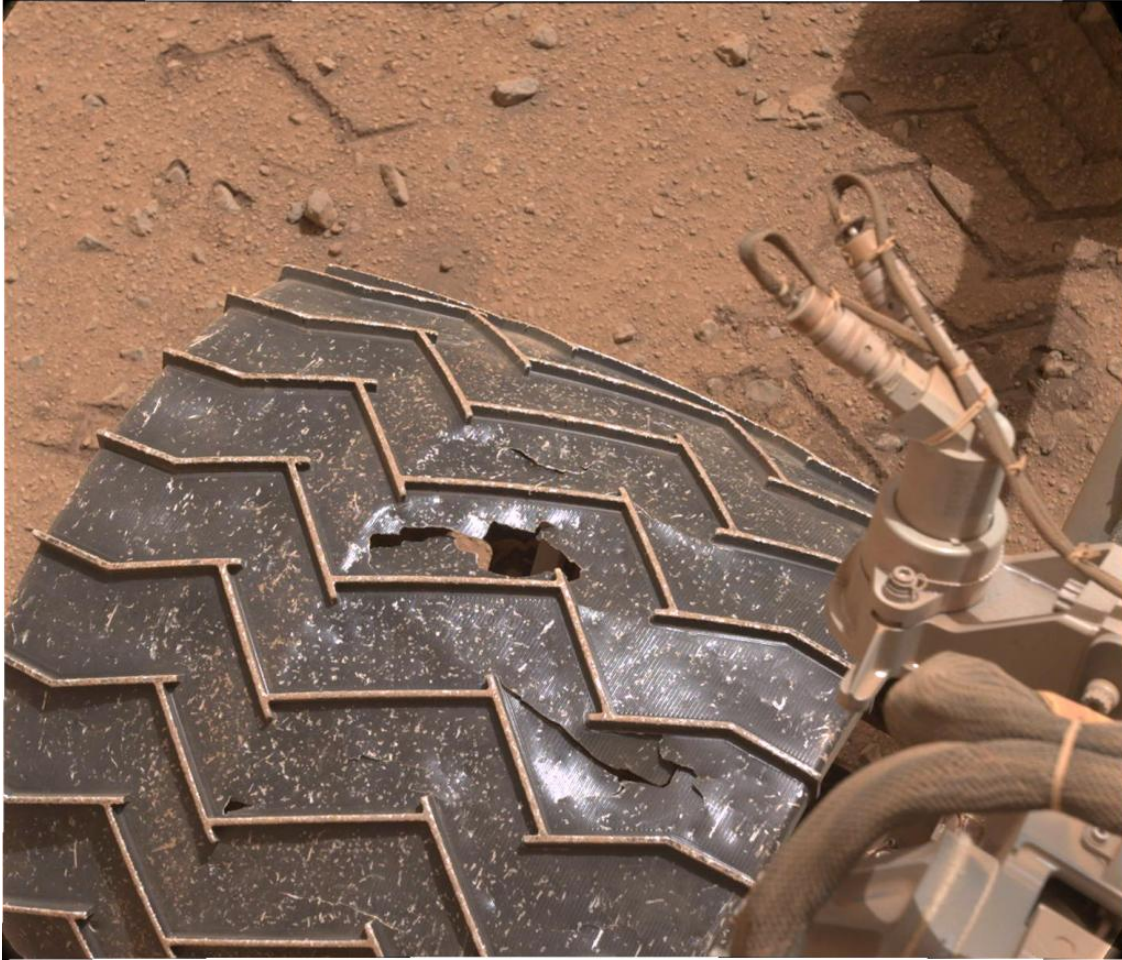
95 to 100



	Start Time ↑ ↓	Mission Name ↑ ↓	Planet Day Number ↑ ↓	MSL Confidence ↑ ↓
 0003ML0000001240100144E01_DRCL	2012-08-09T05:54:41.027Z	Mars Science Laboratory	3	99.9647
 0679ML0028900030303985E01_DRCL	2014-07-04T18:32:17.306Z	Mars Science Laboratory	679	99.9993
 1798ML0092910020702342E01_DRCL	2017-08-27T17:07:20.815Z	Mars Science Laboratory	1798	99.9999



MSL Rover Wheel Degradation



July 2014



August 2017

Summary

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- Fine-tuning Earth-based CNN to adapt it for Mars images was successful
 - Despite differences in image properties, imaging conditions, classes of interest.
 - Results for Mars surface and orbital images
- Classification models were deployed on PDS Image Atlas
 - <http://pds-imaging.jpl.nasa.gov/search/>
- Future work:
 - Continue improving MSLNet and HiRISENet
 - Support more instruments

Funding: Planetary Data System (PDS), Multimission Ground System and Services (MGSS), JPL R&TD

Backup slides

MSL Rover Data Set

- Split by sols (Mars solar day)

	Train Sol 3 - 181	Validation Sol 182 - 564	Test 565 - 1060
Mastcam Left	1491	189	202
Mastcam Right	1935	94	373
MAHLI	320	1357	730
Total images	3746	1640	1305

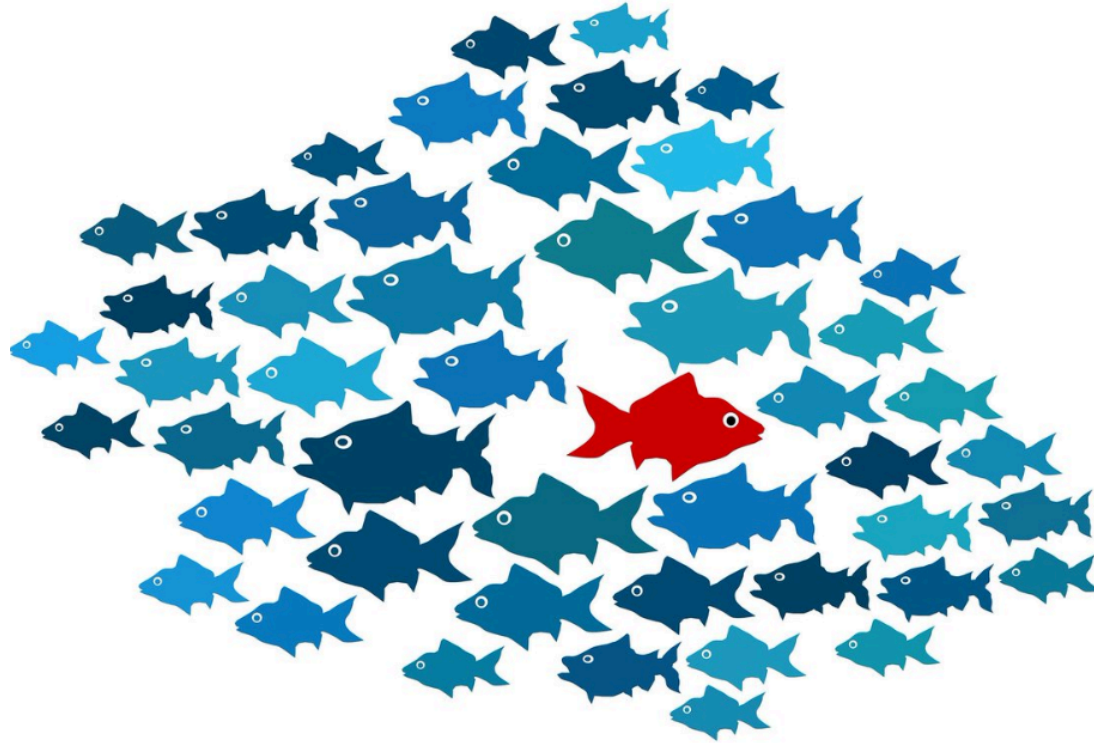
Table: MSL Rover data set by instrument and sol range

- This strategy was chosen to model how the system will be used operationally with an image archive that grows over time. The images were collected from sols 3 to 1060 (August 2012 to July 2015).

MRO HiRISE Data Set

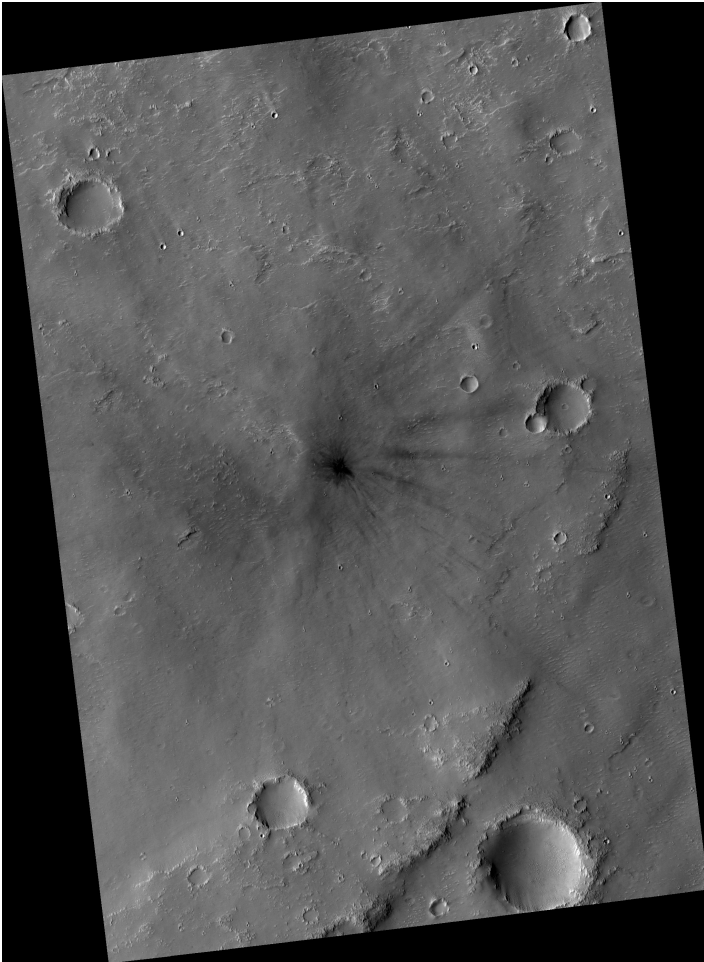
- This data set contains a total of 73,031 landmarks. 10,433 landmarks were detected and extracted from 180 HiRISE browse images, and 62,598 landmarks were augmented from 10,433 original landmarks. For each original landmark, we cropped a square bounding box that includes the full extent of the landmark plus a 30-pixel margin to left, right, top and bottom. Each cropped landmark was resized to 227x227 pixels, and then was augmented to generate 6 additional landmarks using the following methods:
 - 90 degrees clockwise rotation
 - 180 degrees clockwise rotation
 - 270 degrees clockwise rotation
 - Horizontal flip
 - Vertical flip
 - Random brightness adjustment

Salience Detection

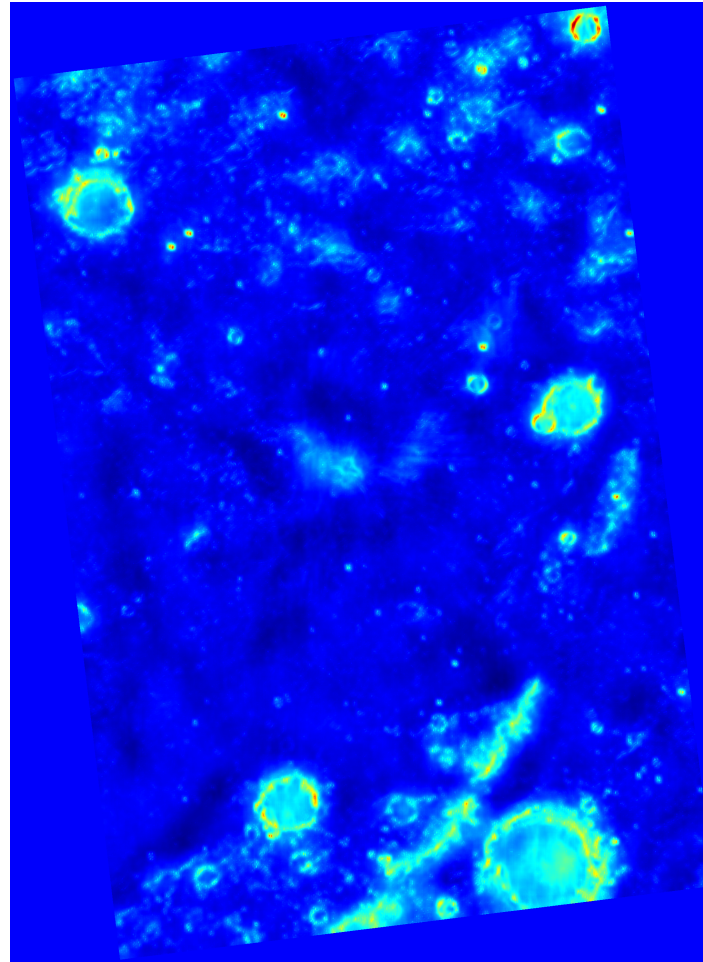


Which is the most unusual fish compares to the others?

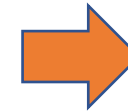
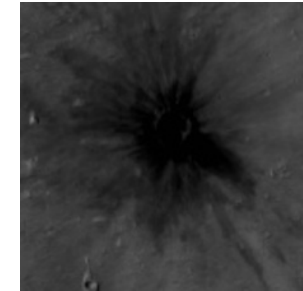
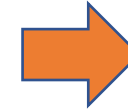
HiRISENet Saliency Detection



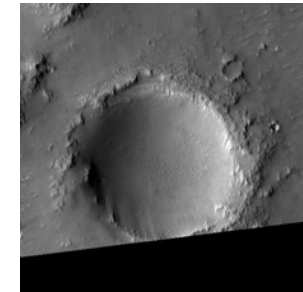
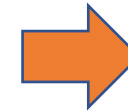
HiRISE map projected image



Saliency map



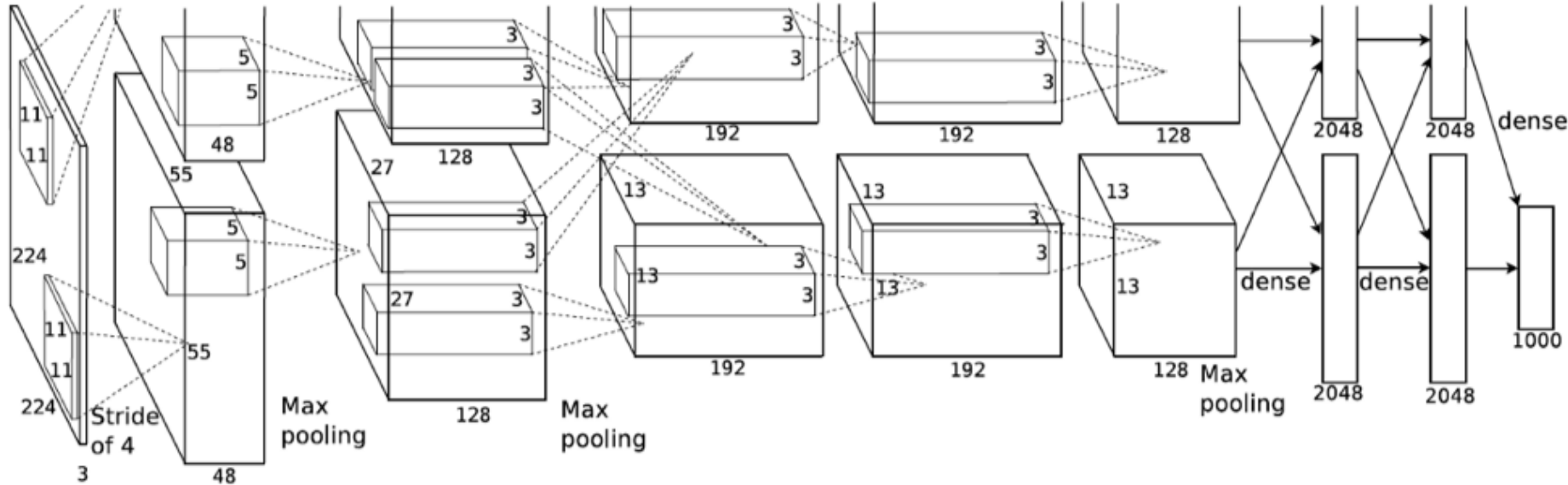
...



Landmarks

Fine-tuning

- Strategy
 - Employ thousands of labeled PDS images
 - Freeze or allow small variations on the weights for initial layers.
 - Boost learning rate on the last layer.

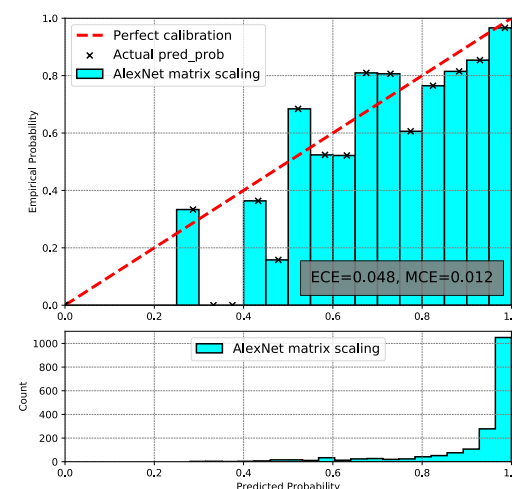
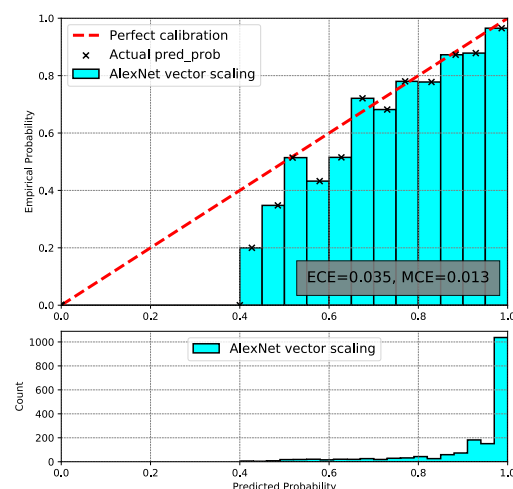
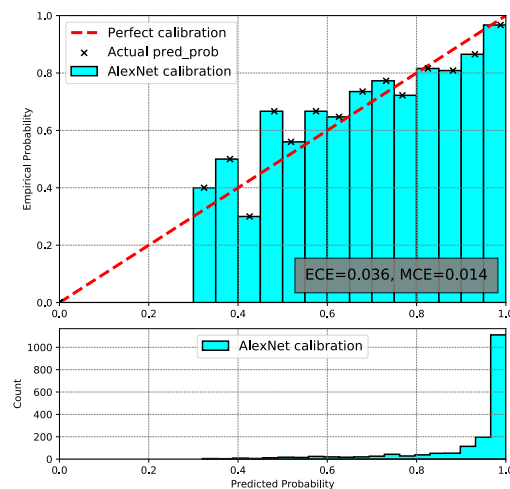
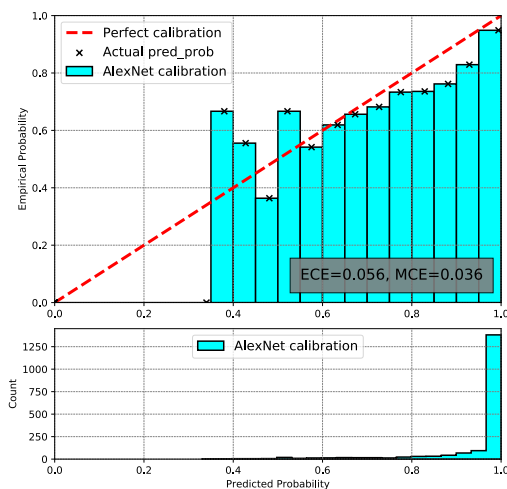


[Alex Krizhevsky, et al, ImageNet Classification with Deep Convolutional Neural Networks, NIPS 2012]

HiRISENet Calibration

Methods	Test accuracy	Test accuracy with 0.9 confidence	ECE	MCE
Uncalibrated	90.00%	93.45%	0.056	0.036
Temperature scaling	90.00% (same)	93.46% (0.01% \uparrow)	0.036 (0.02 \downarrow)	0.014 (0.022 \uparrow)
Vector scaling	88.40% (1.6% \downarrow)	92.13% (1.32% \downarrow)	0.035 (0.021 \uparrow)	0.013 (0.023 \uparrow)
Matrix scaling	89.01% (0.99% \downarrow)	92.82% (0.63% \downarrow)	0.048 (0.008 \uparrow)	0.012 (0.024 \uparrow)

BEST for MRO HiRISE data set!



[Chuan Guo, et al, On Calibration of Modern Neural Networks, ICMP 2017]